Information

Area 1.

Nanotube/Quantum Dot-Polymer Solar Cells

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Nanotube/Quantum Dot-Polymer Solar Cells Abstract

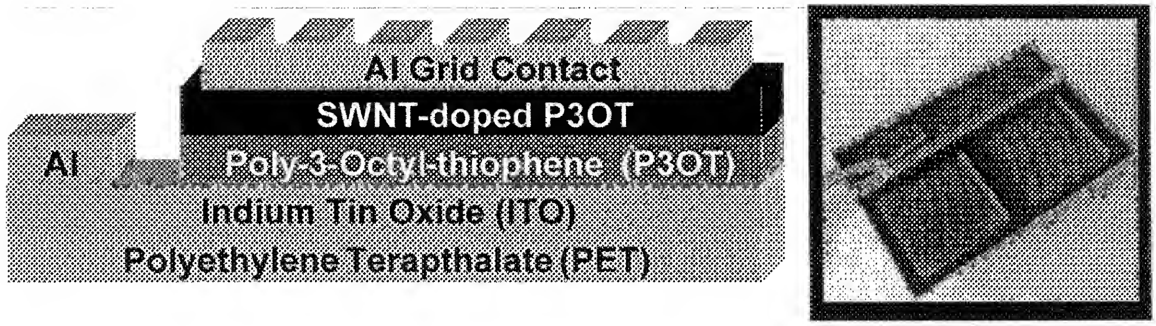
Single wall carbon nanotubes used for this study were synthesized using the pulse laser vaporization technique. The as-produced SWNTs were collected from the condensed region on the quartz tube outside the furnace and purified by modification of the previously reported procedure. Preparation of the SWNT-P3OT composite solutions was performed using a series of mixing and sonication steps as previously demonstrated for other SWNT-polymer systems. Device fabrication involved the use of commercially-obtained, high quality (i.e., < 10 W/sq.) ITO-coated polyethylene terapthalate (PET) substrates. Initially, an intrinsic layer of pristine P3OT is spray deposited (~1-2 mL of the 15 mg/mL solution) onto the masked, 1 in.^{2} active area of the substrate. This is followed with spray deposition of the SWNT-P3OT composite solutions at similar volumes. As seen in Figure 1, completion of the solar cell occurs when aluminum contacts (typical thicknesses of 1000Å) are applied to the ITO and SWNT-P3OT composite film layers.

The homogeneous distribution of SWNTs in a polymer matrix is dependent upon the ability of the polymer chain to associate with the SWNT superstructure. Stable composite dispersions of 0.1% and 1.0% w/w SWNTs in P3OT were produced and analyzed in this study. Optical spectroscopy was conducted to observe the SWNT doping level effects on the absorption properties and infer potential electronic interactions between dopant and polymer. Shown in Figure 2 is an overlay of these spectra where the pristine P3OT shows strong optical absorption at energies >2 eV. As expected, variation in absorption properties for the SWNT-P3OT composites is observed as the doping level increases. Through modification of the SWNT doping level in the polymer, it is possible to alter the absorption pattern of these composite materials. In fact, at these relatively low doping levels, the P3OT shows a significant enhancement in absorption through the near-IR and visible regions. The gray curve for purified SWNTs is offset from the other three for clarity, but indicates the typical complex pattern observed for this spectral range.

Application of SWNT-P3OT composite solutions to the constructed devices was performed using a solution-spray technique onto the ITO/PET substrates. These novel polymeric solar cells were constructed for pristine P3OT, 0.1% w/w, and 1.0% w/w SWNTs in P3OT, and tested under simulated AM0 illumination to determine the respective I-V characteristics. The typical photoresponse observed for pristine P3OT and 1% w/w SWNT-P3OT cells is shown in Figure 3. Although each overlay shows significant enhancement in both I_{sc} and V_{oc} upon illumination, there is an absence of the typical diode "knee" for both cases. The cause of the larger than expected reverse bias currents is under investigation. This effect may be attributed to long-lived energy states for the SWNTs and P3OT or the presence of carrier traps which reduces the I_{sc}.

Further characterization of the composite cells showed a corresponding increase in the I_{sc} as the doping level of SWNTs increased in the P3OT. Figure 4 shows an I-V overlay under the simulated AM0 illumination for the pristine P3OT, 0.1%, and 1.0 % w/w SWNT-P3OT cells in the region of forward bias. Clearly evident is an order of magnitude increase in the I_{sc} from the pristine P3OT to the 0.1% w/w SWNT-P3OT composite cell. An additional increase of ~50% is observed when the doping level reaches 1.0% w/w, with an I_{sc} equal to 0.12 mA/cm^2 for the cell. This result indicates that there is an apparent conductivity effect on the I_{sc} in the composite films which can be controlled by SWNT doping. Interestingly, the measured V_{oc} of 0.98 V is signficantly higher than the recent report, where they postulated that the energy difference in the HOMO-LUMO levels of the SWNT/polymer junction is responsible for the open-circuit-voltage. An explanation of this current result may reside in the purity and defect density of the SWNTs.

Our approach to maximizing the charge separation and carrier transport in SWNT-doped P3OT cells is through attachment of covalent semiconducting quantum dots to the SWNTs (see Figure 5a). Shown in Figure 6b is a tapping-mode atomic force micrograph (AFM) of our resulting CdSe-en-SWNT complexed sample. Incorporation of this material into similar P3OT composite solar cells as described here, is currently under investigation.



(a) (b)

Figure 1. (a) Schematic representation and (b) image depicting the composition of fabricated SWNT-P3OT flexible solar cells

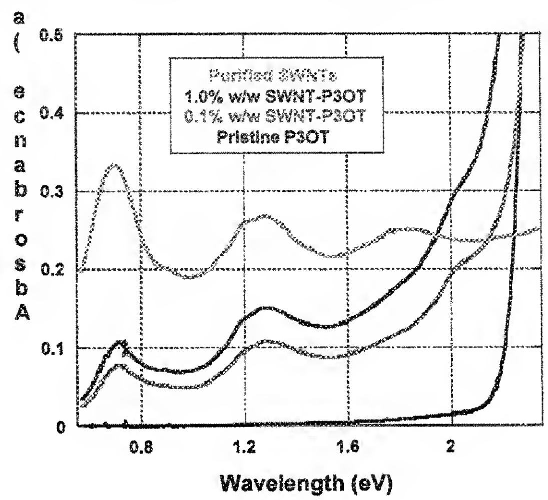
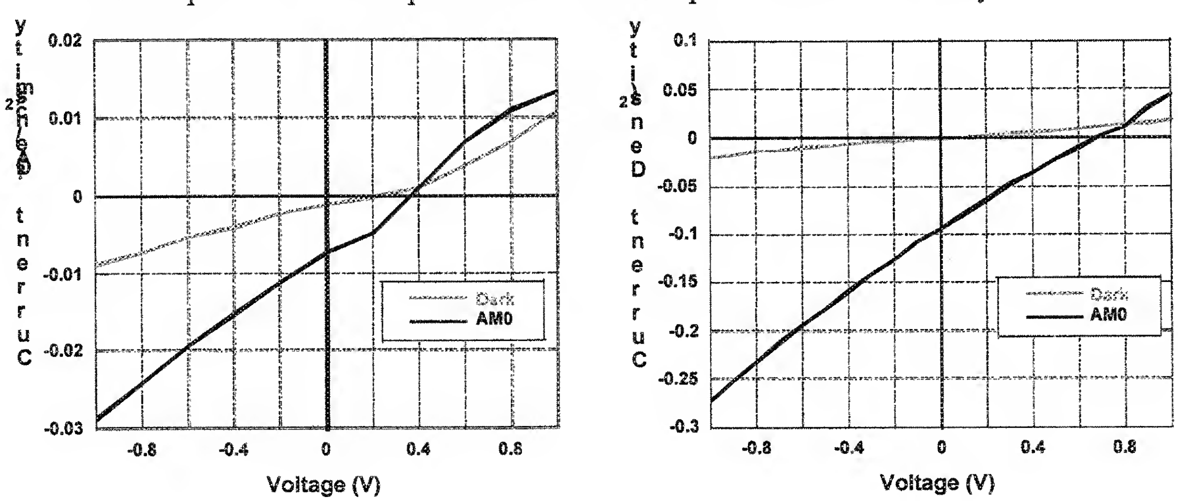


Figure 2. Optical absorption overlay for thin films of pristine P3OT (black), 0.1% w/w SWNT-P3OT composite (red), 1.0% w/w SWNT-P3OT composite (blue), and purified SWNTs (gray). Enhancement in absorption for the composites relative to the pristine P3OT is clearly observed



(a) (b)

Figure 3. Characteristic I-V plots in the dark (gray) and under simulated AM0 illumination (black), displaying the photoresponse for (a) pristine P3OT and (b) 1% w/w SWNT-P3OT composite solar cells

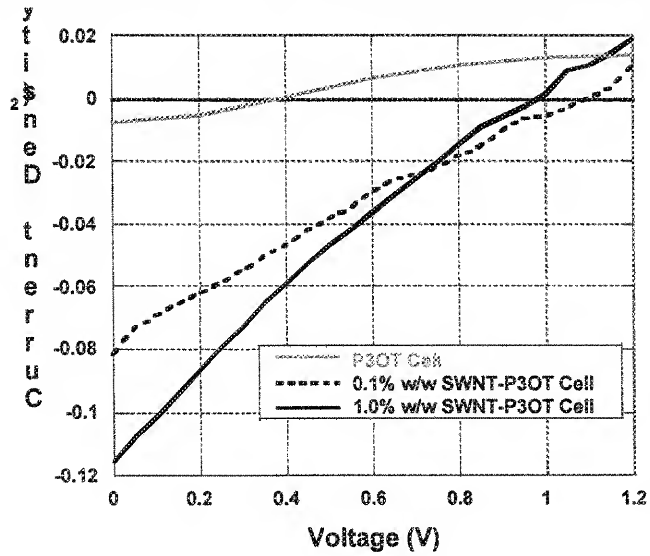
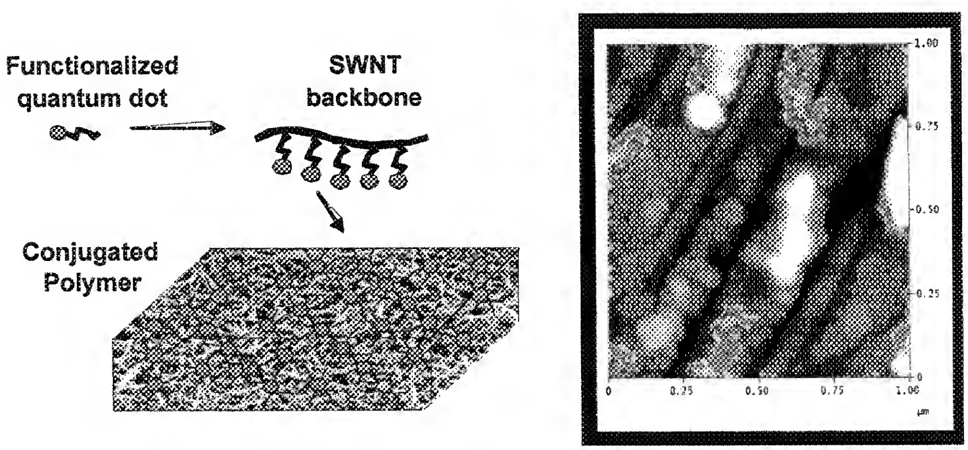


Figure 4. Overlay of the I-V relationship under simulated AM0 illumination for pristine P3OT (gray), 0.1% w/w SWNT-P3OT composite (black dashed), and 1.0% w/w SWNT-P3OT composite (black line) solar cells.



(a) (b)

Figure 5. (a) Schematic representation of the approach to conjugate quantum dots with SWNTs prior to dispersion in the conducting polymer; (b) AFM image of CdSe-en-SWNTs to be used as dopant in future SWNT-P3OT solar cells